The operative Tree based Distributed Clustering Routing Policy for Energy Efficiency in Wireless Sensor Networks

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Abstract-: The energy efficiency the most important andvital performance metrics of wireless sensor networks (WSNs) as the lifetime of battery is limited. Energy efficiency helps in deciding the long running WSNs functionality. There are different solutions have been presented for energy efficiency based on hardware and software. However, particularly clustering based routing algorithms are most promising approaches and hence studied extensively for energy efficiency and load balancing. The existing clustering methods having drawbacks like cluster heads suffered from excessive energy consumption due to all loads on it, therefore this can be later overcome by placing the gateways in WSNs which can acts cluster head with more energy sources in it. However with use only gateways with clustering again imposing limitation of energy consumption as gateways are also battery operated as well as load balancing is not addressed. In this paper, aim is to design and simulate novel tree based distributed for energy efficiency and data aggregation in WSNs. The proposed method is composed of three main steps such as hop tree building from source node to the destination sensor node, then cluster head selection and cluster formation. Finally the efficient and reliable route setup for data transmission is presented. The working of proposed algorithm is based on existing SPT (shortest path tree) routing method. The experimental evaluation of proposed method is done using NS2. The simulation results claims that proposed method is outperforming the existing energy efficient routing solutions.

Keywords Consumption, Energy Efficiency, Network Lifetime, Hop tree, Energy clustering, Cluster head

I. INTRODUCTION

Wireless sensor network consist of multiple devices and sensors used to monitors physical environment conditions. In this network every node or sensor having routers and gateways to create WSN system. Centralized gateway connect all the nodes in the network, its establish connection between network nodes wirelessly [1]. We can establish long distance and reliable connection with help of routers. This functional diagram in figure 1 is shows modular design approach which provides the flexible and versatile platform for the addressing the variety of applications needs through the efficient routing. For the deploying the sensors in the network field the signal conditioning block can be reprogrammed or replaced. Wireless sensing node uses the different of sensor [2]. As per the given application the requirement of radio links may be swapped. For the bidirectional communication these application needs wireless range [3].

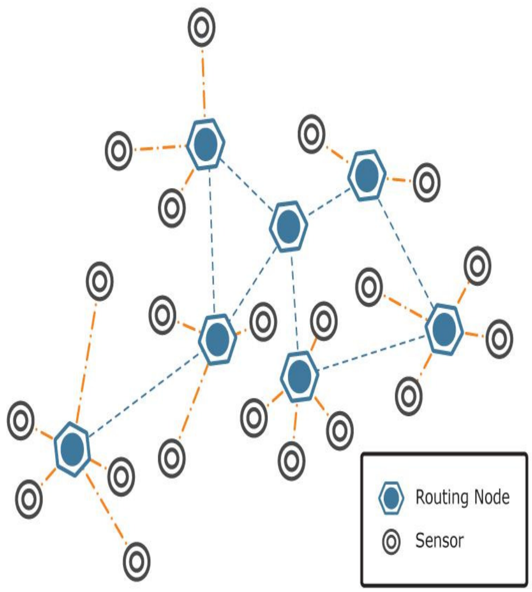

Figure 1: Representation of Wireless Sensor Nodes and Routing Nodes

A sensor network is defined as being composed of a large number of nodes with sensing, processing and communication facilities which are densely deployed either inside the phenomenon or very close to it. Each of these nodes collects data and its purpose is to route this information back to a sink [3]. The network must possess self-organizing capabilities since the positions of individual nodes are not predetermined. Cooperation among nodes is the dominant feature of this type of network, where groups of nodes cooperate to disseminate the information gathered in their vicinity to the user. Recent advances in micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics have made possible to develop low-cost, low-power, multifunctional sensor nodes that are small in size and communicate freely in short distances [4]. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes. Sensor networks represent a significant improvement over traditional sensors, which are deployed in the following two ways [4]:

• **Sensors can be positioned far from the actual** phenomenon, i.e., something known by sense perception. In this approach, large sensors that use some complex techniques to distinguish the targets from environmental noise are required.

• **Several sensors that perform only sensing can be** deployed. The positions of the sensors and communications topology are carefully engineered.

They transmit time series of the sensed phenomenon to the central nodes where computations are performed and data are fused. The position of sensor nodes need not be engineered or pre-determined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities. The main goal of data aggregation algorithms is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. WSN offer an increasingly attractive method of data gathering in distributed system architectures and dynamic access via wireless connectivity [6]. Data aggregation attempts to collect the most critical data from the sensors and make it available to the sink in an energy efficient manner with minimum data latency. Data latency is important in many applications such as environment monitoring where the freshness of data is also an important factor**.** It is critical to develop energy efficient data aggregation algorithms so that network lifetime is enhanced [7] [8]. There are several factors which determine the energy efficiency of a sensor network such as network architecture, the data aggregation mechanism and the underlying routing protocol. The functionality of the sensor network should be extended as long as possible. In an ideal data aggregation policy, each sensor should have expended the same amount of energy in each data gathering round. A data aggregation policy is energy efficient if it maximizes the functionality of the network. If we assume that all sensors are equally important, we should minimize the energy consumption of each sensor. This idea is captured by the network lifetime which quantifies the energy efficiency of the network. Network lifetime, data accuracy, and latency are some of the important performance measures of data aggregation algorithms. The definitions of these measures are highly dependent on the desired application [9].

There are number of data aggregation methods [11] [12] [13] presented in literature recently with goal of optimizing the performance of energy efficiency and routing efficiency based on different methodologies like clustering, optimization methods like PSO, GA etc. However, energy efficiency is always prime objective while designing any new routing protocol for WSNs. In this paper, we proposed distributed and tree based energy efficient clustering routing protocol for energy efficiency and network reliability performance. The proposed method is named as Tree based Distributed Clustering Routing Protocol (TDCRP). In section II, the related works on different energy efficient techniques is discussed. In section III, the proposed algorithms are designed and presented. In section IV, simulation setup and results are presented. Finally in section V, conclusion and future work discussed.

II. RELATED WORKS

Dongfeng Xie et.al (2013)

In [1], author proposed novel cluster formation strategy from the point of cluster members. They presented their observation that rather than choosing the proximate cluster head, a cluster member may prefer to select a node that makes the total packet delivering energy consumption least or the co-alive lifespan longest.

Fifi Farouk et.al (2014)

In [2], author proposed stable and energy-efficient clustering (SEEC) protocol for heterogeneous WSNs. In addition, the extension to multi-level of SEEC was introduced. This method was depends on the network structure that was divided into clusters. Each cluster had a powerful advanced node and some normal nodes deployed randomly in this cluster. In the multi-level architectures, more powerful supper nodes were assigned to cover distant sensing areas. Each type of nodes has its role in the sensing, aggregation or transmission to the base station.

Long Cheng et.al (2015)

In [3], author introduced seamless streaming data delivery (SSDD) protocol for multihop cluster-based WSNs with MEs. Different from existing works, they concentrated on the localized mobility support for the delivery of streaming data in hierarchical WSNs. By introducing a cross-cluster handover mechanism and a path redirection policy, SSDD efficiently maintains the end-to-end connectivity between a source and a ME during data transmission while avoiding most of the overhead in broadcasting the location of the ME as it moves in the sensing field.

Jalal Habibi et.al (2015)

In [4], author introduced framework to analytically derive the best achievable performance that can be obtained by any distributed routing algorithm based on the shortest-path approach. Given a network configuration and an energy consumption model, their presented framework provides the optimal link cost assignment which yields the maximum lifetime in a distributed shortest path routing strategy. The optimal solution to distributed minimum-cost routing problem in sensor networks was presented.

Hai Lin et.al (2015)

In [5], they introduced the clustering protocol called Fan-Shaped Clustering (FSC) to partition a large-scale network into fan-shaped clusters. Based on this clustering policy, different energy saving methods was proposed by authors, such as efficient cluster head and relay selection, locality of re-clustering, simple but robust routing and hotspot solution.

Dapeng Wu et.al (2015)

In [6], author proposed method to enhance the network lifetime and meet the demand of a green wireless network, a dynamic gradientaware hierarchical packet forwarding mechanism. According to the relative positions of nodes, gradient-aware clusters were established. Consequently, considering the energy conversion efficiency and relative distance, cluster heads were selected reasonably. Furthermore, by exploiting the available energy and the number of cluster members, packets can be forwarded to the sink in an energy-efficient manner.

HalilYetgin et.al (2015)

In [7], author introduced the novel joint optimal design of the physical, medium access control (MAC) and network layers to maximize the NL of the energy-constrained WSN. The problem of NL maximization was formulated as a non-linear optimization problem encompassing the routing flow, link scheduling, and transmission rate and power allocation operations for all active time slots.

Peng Cheng et.al (2015)

In [8], they investigated the data forwarding strategy design for accurate remote state estimation in multi-hop wireless networks. Based on different computational capability of relay nodes, they proposed two relay strategies, namely, Direct Forwarding Strategy (DFS) and Local Processing and Forwarding Strategy (LFS). Then they introduced Event-triggered Forwarding Strategy (EFS) which was able to balance the estimation accuracy and relay energy consumption.

Mianxiong Dong et.al (2016)

In [9], author introduced a novel event data collection approach named RMER (Reliability and Multi-path Encounter Routing) for meeting reliability and energy efficiency requirements. They shown that energy consumption can be greatly reduced, thereby enabling further increased network lifetime.

Sicong Liu et.al (2017)

In [10], author proposed two algorithms to efficiently construct the IPF, including Hierarchical Skeleton-based Construction Algorithm (HSCA) and Value Estimating Substitution Algorithm (VESA). Both algorithms were obeying the typical hypotheses on WSN settings and the gossip-styled propagation principle. They proposed advanced approaches of construct the IPF to tackle the challenges of its practical applications, such as obstacles, task priorities and sensor energy budget.

III. METHODOLOGY

The proposed routing protocol (TDCRP) is composed of three main steps such as hop tree building, then clustering and finally route setup and maintenance. The cluster formation is most important and vital for clustering methods. Selection of appropriate cluster head with objective of energy efficiency is designed in this paper. Figure 2 is showing the simulation flowchart with details of performance metrics and routing methods simulated and evaluated. There are three routing methods simulated and evaluated in this paper such as AODV, CAODV (clustered AODV) and proposed TDCRP.

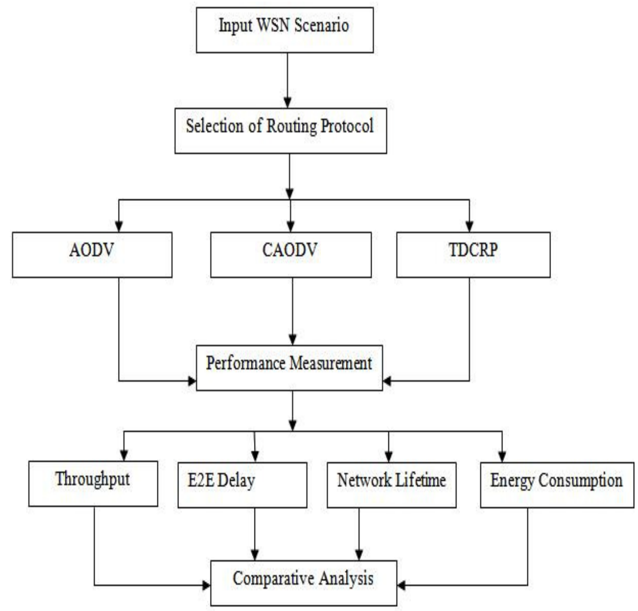

Figure 2: Simulation Flowchart

Below three algorithms are designed for three phase proposed routing protocol.

Notations

CoH: Configuration of Hop

LTT: Link-To-Tree

NH: Next Hop

CoC: Configuration of Cluster

Phase I: Building Hop Tree

Wherever any node in network ready to send data over intended recipient, then this algorithm will start constructing the tree.

Algorithm 1: Hop Tree Construction

1. The Sink floods an CoH message with LTT=1;

2. For each node u that received an CoH message

3. If LTT(u)> LTT(CoH)

4. NH(u)=ID(CoH); % NH (u) stores the next hop of node u

5. LTT (u)=LTT (CoH);

ID(CoH)=ID(u);

LTT (CoH)= LTT (u)+1;

State(CoH)=State(u);

6. u transmits the CoH message to its neighbors;

7. Else If (LTT (u)==LTT (CoH) &State(NH(u))< State(CoH))

8. NH(u)=ID(CoH);

Phase II: Cluster Creation and Cluster Head Selection

When an event occurs, a cluster based on the nodes which detect it will be formed. The key process of the cluster formation phase is the election of the leader node (called Coordinator) for the cluster, and the information delivery in this phase is by means of Configuration of Cluster Message (CoC). CoC is also a four-tuple: < Type, ID, LTT, State>, where ID is the identifier of the node that started the MCC message, LTT and State fields store the LTT and State value of the node with the identifier ID separately. Algorithm 2 is showing the processing of this phase.

Algorithm 2: Cluster Creation

1. For each node u that detected the event

2. Role(u)=Coordinator;

3. u creates an CoC and broadcasts it;

4. For each node u that received a CoC message of the same event

5. If LTT (CoC)<LTT(u)

6. Role(u)=Collaborator;

7. u retransmits the CoC;

8. Else If LTT(CoC)==LTT(u) & State (CoC)>State (u)

9. Role(u)=Collaborator;

10. u retransmits the CoC

Phase III: Route Setup and Update

Finally, after cluster formation, next step is to establish the route between source and destination for data transmission. As per the current activities in network hop tree is updated. Algorithm 3 is showing the process of this phase.

Algorithm 3: Route Setup

1. If LTT(v)==0 %Node v is a Coordinator;

2. There is no need to build path;

3. Else If Energy(NH(v))<Threshold_Energy& Node v can find a neighbor who satisfies: a) its residual energy is greater than Threshold_Energy, b) with less HTS.

4. v informs (or sends a RM along the Path in reverse direction to inform) the nodes within event field to enter the Forced Path Building phase.

5. Else

6. v appends itself to the Path and sends a PBM message to its next hop;

7. For each node u that received a PBM message

8. If LTT (u)==0

9. Path building successes,;

10. Else

11. u acts similarly to the behaviors shown in the Lines 3-6. % forced Path Building phase

12. The node with the smallest HTS and best state in the event field will be chosen as the new Coordinator, denoted by u

13. NH(u)=v, v is a neighbor of u with the less HTS and best state;

14. u appends itself to the Path and sends a FPBM to its next hop;

15. For each node w received an FPBM message

16. If w==Sink

17. Forced path building successes.

18. Else

19. w acts similarly to the behaviors shown in the Lines 13-14 ;

IV. RESULTS AND DISCUSSION

The simulation is conducted using well know simulator NS2. Table 1 is showing the properties and parameters used for network designing.

TABLE 1: NETWORK SIMULATION PARAMETERS

Number of Sensor Nodes	50, 100, 150, 200, 250, 300
Traffic Patterns	CBR

Network Size	1000 X 1000
Simulation Time	100 s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV/CAODV/TDCRP
MAC Protocol	802.11
Transmission Protocol	CBR

Based on above settings, the performance is measured for each network designed with every routing protocol. The graphs of performance are showing below.

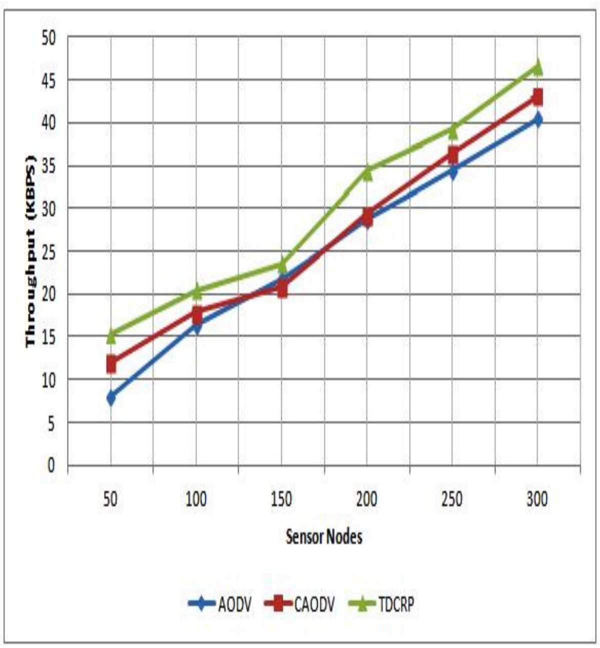

Figure 3: Throughput Performance Evaluation

Figure 3 is showing the performance of throughput measured for each network and each routing protocol. The proposed protocol achieving better throughput performance as compared to existing clustering based routing protocol and AODV. Similarly the performance of delay is showing in figure 4 which is claims that TDCRP is having reduced the delay significantly as compared to CAODV.

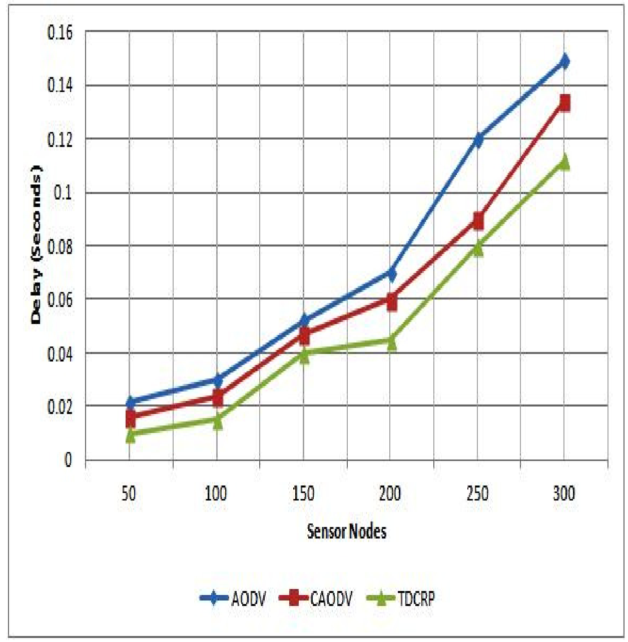

Figure 4: End to End Delay Analysis

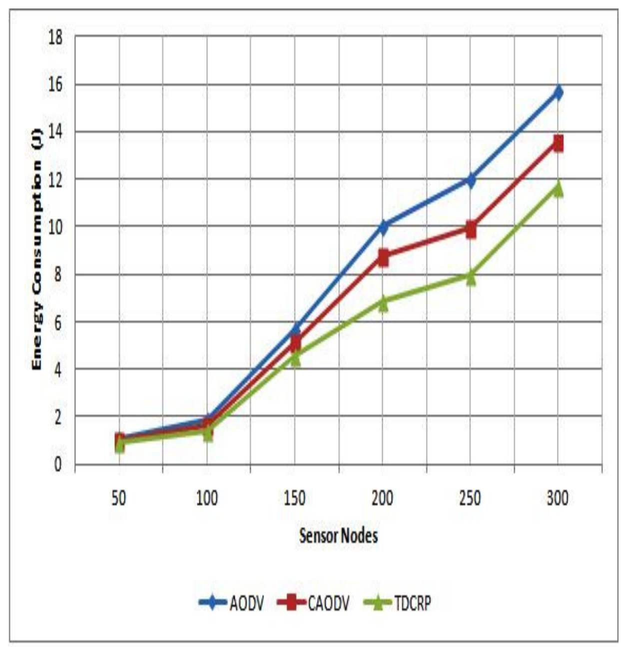

Figure 5: Energy Consumption Performance Analysis

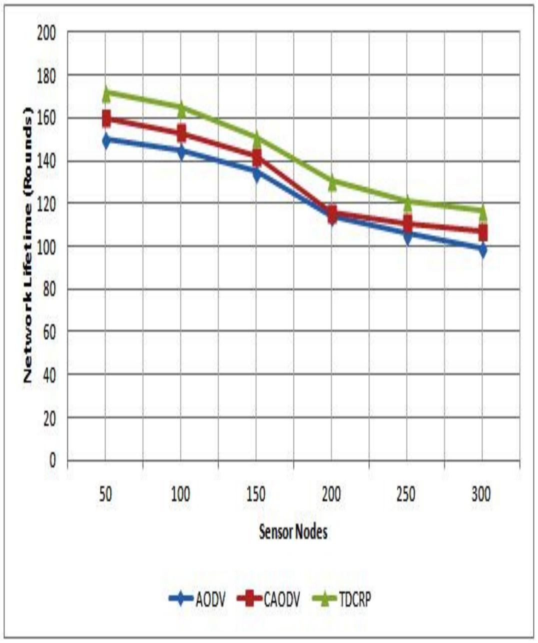

Figure 6: Network Lifetime Performance Analysis

Figure 5 and 6 are showing the energy efficiency related performance. The goal of TDCRP is to minimize the energy consumption and improve the network lifetime. The results show that proposed method minimized the consumption of energy and hence enhance the network lifetime significantly. This is possible due to distributed nature of cluster formation and communication in WSNs.

V. CONCLUSION AND FUTURE WORK

Wireless Sensor Networks are widely used in most important applications in day to day life such as weather monitoring, security monitoring, event detection, alarming, disaster management etc. As sensors are having limited battery power, there is important to use energy efficient communication methods while designing application specific WSNs. The energy efficiency majorly is achieved through the routing functionalities. In this paper, our aim was to design distributed tree based clustering routing protocol for energy efficiency. We presented the algorithms designed for proposed cluster based routing protocol in this paper. The simulation results of TDCRP is measured for small to large networks in order to check the reliability and energy efficiency performance against existing routing solutions. The results show that energy efficiency is improved by approximately 17.5 %. For future work, we would like to introduce the reinforcement learning method for cluster head selection and clustering process to further improve the energy efficiency performance.

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